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Superseding ARP587B

Balancing Machines - Description and Evaluation Horizontal, Two-Plane, Soft-Bearing Type for Gas Turbine Rotors

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE EG-1A Balancing Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

FOREWORD

The prior A version of this document achieved wide acceptance and use around the world by turbine engine manufacturers and overhaulers. The extensive application of this ARP resulted in some suggestions for improvements that are addressed by this B revision of the document.

To make the document more user friendly, the structure has been rearranged and explanatory text added. The requirement for outboard proving rotors has been deleted, along with the associated tests. Duplications of certain other tests have been eliminated. The format of all tests has been standardized, and the requirements for each test together with the test procedure consolidated into a single section of the document. End-drive interface dimensions have been harmonized with those in ARP1382, and specifications for work support envelops and rotor enclosure mounting pads deleted. Capacities and dimensions for three smaller classes of machines have been added to take into account the requirements of the small turbine engine, accessory, and missile industries.

ARP1340 (Periodic Surveillance Procedure for Horizontal Balancing Machines) has been incorporated into Section 10 herein.

TABLE OF CONTENTS

1. SCOPE:

1.1 This Aerospace Recommended Practice (ARP) specifies the requirements of balancing machines that make them suitable for the subject class of work. It was developed for soft-bearing balancing machines but may also be used for hard-bearing machines until ARP4048 is issued for that type of machine.

1.2 Particular note should be taken that this ARP examines only the capability of a balancing machine to indicate the correct amount of dynamic or static/couple unbalance in specified proving rotors. Such rotors are commonly used for testing balancing machines to provide precisely controlled and comparable test results. Further tests of a particular machine may be necessary to assess the capability to balance rotors of different weights and configurations, rotors with outboard c.g. and/or correction planes, and those with disturbance causing features, such as rotors subject to blade scatter, windage, etc.

1.3 This ARP specifies dimensional and performance requirements in the following areas:

a. Machine capacity relating to weight and physical dimensions of the rotors that can be balanced

b. Accuracy of amount and angle indication

c. Sensitivity and linearity of amount indication

d. Ability to separate dynamic unbalance into two planes or into static and couple unbalance

e. Balancing speed and direction of rotation

f. Drive requirements

g. Proving rotors, test masses, and storage containers

2. PURPOSE:

2.1 This ARP delineates the technical specifications for the rotating type of soft-bearing, two-plane (i.e., dynamic) balancing machine used for measuring the amount and angle of unbalance in one or more than one plane in aircraft type turbine engine, accessory and missile rotors.

2.2 This document also delineates performance tests to be used to ensure conformance with the requirements in this ARP.

2.3 This document was prepared to describe dimensional and performance requirements for machines capable of balancing most rotors either now in service or to be put into service in the foreseeable future. This will enable both rotor and balancing machine manufacturers to standardize, avoiding the need for separate tooling to adapt a particular rotor to a variety of machines of one capacity range. It can also be used as a general specification by purchasers ("Users") in procuring suitable balancing machines from manufacturers ("Suppliers").

2.4 To make this ARP sufficiently flexible so that it can be adapted to a variety of applications (such as rotors to be balanced by the accessory and missile industries, where a wide range of balance tolerances are specified), the test procedures have been written in terms of A units rather than fixed physical values such as ounces, ounce·inches, or microinches.

3. CONFORMANCE REQUIREMENTS:

The User or the User's designated inspector shall assure that the machine meets the requirements of this ARP. Such assurance shall be ascertained by individual verification of full machine conformance in all of the following three areas:

3.1 Conformance with each line item of the Capacity and Dimensional Requirements in Table 1.

3.2 Conformance with each of the performance tests in Section 9.

3.3 Conformance with User designated contractual requirements (see Appendix C).

NOTE: To keep the test procedures short enough to be practical, some requirements in Table 1 and elsewhere are not fully proven either through the line item verification or the tests in Section 9. Such requirements are intended as a guide to the balancing machine manufacturer, and will have to be covered by the warranty and reputation of the manufacturer.

4. CAPACITY AND DIMENSIONAL REQUIREMENTS:

Table 1 lists the capacity and dimension requirements for each class of machine.

TABLE 1 - Dimension and Capacity Requirements

Characteristic		Dimensions and Capacities					
4.1	Machine Class (lb)	10	30	100	300	1000	3000
4.2	Rotor Weight (lb)						
4.2.1	Max[1]	20	50	150	450	1500	4500
4.2.2	Min	0.3	1	3	45	150	450
4.2.3	Max per Support[1]	10	30	100	300	1000	3000
4.2.4	Max negative load on one support	3	10	30	45	150	450[2]
4.2.5	Max moment per suppoort (offset load - lb'in)	10	30	100	300	1000	3000
4.2.6	Max Wn^2 value[3] $(lb \cdot rpm^2 \cdot 10^6)$	65	65	400	3300	5500	12000

TABLE 1 (Continued)

	Characteristic	Dimensions and Capacities					
4.3	Rotor Size (in)						
4.3.1	Max diameter (in rotor enclosure, mounted in tie bar frame)	10	12	22	25	55	66
4.3.2	Max diameter of outboard rotor (in rotor enclosure)	- -[4]	- -[4]	- -[4]	- -[4]	90	110
4.3.3	Max distance between support centerlines[5]	15	15	25	50	75	100
4.3.4	Shaft dia. range on rolls[6] min.	0.2	0.3	0.4	0.5	1	1.5
	max.	1.2	1.5	3.5	7	9	12
4.3.5	Saddle bearing ID[7]	3	4	6	10	13	15
	Width		0.75	1	1.5	2	2
4.4	Unbalance Measurement (in)						
4.4.1	Sensitivity (see B.10) 1 A unit	10	10	10	14.5	14.5	14.5
4.5	Drive and Balancing Speeds						
4.5.1	Horsepower[8,9]	0.15	0.75	2	10	30	75
4.5.2	Rotor (or rotor pulley) driven diameter (in)[10]	0.5-4	0.5-4	0.8-6	1-9	2-12	3-18
4.5.3	Max belt width (in)[8]	0.5	1.0	1.5	2.5	5	6
4.5.4	End-drive interfaces (Nm ratings) (For dimensions see ARP1382)	NA	NA	NA	80	80	250
					250	250	700
						700	2250
4.5.5	Balancing speed range (rpm)[11] min	500	500	500	500	500	500
	max	3000	3000	2500	1500	1500	1500
4.5.6	Test speed range (rpm)[11] min	1500	1200	1000	800	800	600
	max	3000	2500	2000	2000	1500	1000
4.6	Proving Rotors						
4.6.1	Design	.... per Appendix A[12]					
4.6.2	Weight (lb)	11	11	52	52	170	460

TABLE 1 (Continued)

[1]Overloading of the balance machine beyond 4.2.1 and 4.2.3 is not recommended unless approved by the balancing machine manufacturer.
[2]If the 3000 lb class machine is to accommodate certain large, fan-type rotors, a maximum negative load of 700 lb must be specified.
[3]The stated values assume that the rotor c.g. lies within the midthird of the distance between the machine supports. If not, the Wn^2 capacity at the near support is reduced, particularly in case of outboard rotors, and must be clarified with the manufacturer.
[4]Depends of height of plinth over floor.
[5]Provision shall be made to extend the distance between supports either by providing an option at the time of purchase or by a modification kit which may be purchased later.
[6]Applies only if the machine is equipped with roller carriages.
[7]Applies only if the machine is equipped with saddle bearings.
[8]Approximate guideline. The User should specify to the Supplier the horsepower requirements at specific balancing speeds. For belt-drive, full horsepower is intended to be transmitted only by the largest pulley diameter and belt width. For other details on the electrical specifications for the drive see also Appendix C.
[9]The machine shall be capable, six times within an agreed upon time period, of accelerating to balancing speed and then stopping that User rotor which requires the most drive power.
[10]Applies only to machines with belt-drive. Application of the belt to the workpiece shall be possible over the full distance between supports as stated in 4.3.3, either between or outside of the supports.
[11]The machine shall be capable of driving and balancing rotors at continuously variable speed in both directions of rotation over the speed range stated in 4.5.5.
[12]New, simplified proving rotors for all machine classes are being developed in ARP4162. Once this ARP becomes available, it may be used in place of the rotors listed in Appendix A.

5. PROVING ROTORS:

5.1 Tests With Inboard Proving Rotors:

Each balancing machine shall be tested with the appropriate size of inboard proving rotor specified in 4.6.

NOTE: In case the machine is to be used for balancing outboard rotors, it should be tested with the actual rotor as agreed between Supplier and User.

5.2 Rotors and Accessories:

All proving rotors shall consist of (be equipped with) the following items complete and in accordance with drawings and specifications herein:

a. Proving rotor with bearings
b. Test masses as listed in Section 9, Table 2
c. Saddle bearing inserts to adapt the support saddle bearings to the proving rotor bearings
d. Proving rotor storage box

5.3 Commonality of Accessories:

In those cases where proving rotor accessories are common to more than one proving rotor, it shall not be necessary to provide duplicate sets of accessories for each proving rotor. This shall apply to bearings, bearing adaptors, and test masses maintained at a given User or Supplier facility, or to be shipped to such a facility for tests.

5.4 Proving Rotor Running in Rolling Element Bearings:

If User rotors are to be balanced in stators, cradles, or rolling element bearings, the balancing machine must be equipped with saddle bearings. During the tests, the proving rotor must be equipped with rolling element bearings supported in the machine saddle bearings. Proving rotor bearing outer races must then be held perpendicular to the rotor shaft axis, usually within 0.0005 in total axial runout.

5.5 Proving Rotor Running on Twin-Roller Saddle Inserts:

Alternatively, the proving rotor journals may be supported during the tests on twin-roller inserts fitted into the machine saddles, provided that the saddles of the left and right machine supports are rigidly connected with each other during the tests by a tiebar frame.

NOTES:

1. The requirements in 5.4 and 5.5 only apply if the User plans to balance rotors that are to be mounted in the machine using their own stators, cradles, or rolling element bearings. The requirement is intended to prove that the machine supports have sufficient vertical axis freedom to function properly under such rotor mounting conditions.

2. If the User does not plan to balance rotors in stators, cradles or rolling element bearings, the tests must be run by letting the proving rotor journals rest directly on the machine support roller carriages. No rigid connection is then required between the left and right roller carriages.

6. TEST MASSES:

6.1 Required Test Masses:

The test masses required for the Performance Tests are listed in Section 9. Their unbalance values are based on the unbalance Test Unit System (see B.11). Their dimensions and weights shall be certified to the values shown in Appendix A, Figure A2.

6.2 Special Test Masses:

Test masses other than those specified in this document shall be provided when special tests are required that are not specified herein. This also applies to tests with outboard rotors (see note in 5.1). Such test masses shall conform in design, specifications, and dimensional and weight tolerances to those specified in Appendix A, Figure A1B respectively A2.

7. GENERAL TEST CONDITIONS:

7.1 Scope of Tests:

The specific performance requirements preceding each test in Section 9 have been written to define certain characteristics of the machine. Conformance with the tests constitutes what is considered minimum proof that the machine will meet these requirements. The test procedures will not prove conformance with all requirements over the full range of all variables, neither will they measure nor define the exact reasons for nonconformance in a given test.

Failure of a machine to conform may be due to shortcomings in specific components or to more general reasons such as lack of ruggedness, improper leveling or anchoring to the floor, etc.

7.2 Operator Furnished by User or Supplier:

When performing these tests, the User shall provide an examiner trained in the use of balancing machines. The Supplier shall instruct the User's representative in the use of the machine. The User shall either operate the machine or be satisfied that the same result as the Supplier's operator could be obtained. The Supplier shall ensure that the written operating instructions are followed by the User.

7.3 Verification of Rotor and Test Masses:

The Supplier and User shall verify the certification and location of the test masses, and that they and the proving rotor conform to the applicable specifications in Appendix A.

7.4 Test Sequence and Evaluation:

The tests described in Section 9 shall be run in the sequence as listed. Each test generally requires that:

a. The appropriate proving rotor be run in the machine
b. Unbalance be measured and the readings recorded in one of the Test Logs provided in Section 9
c. The recorded readings be plotted in the polar graph in Section 11
d. The overlay of Section 12 be placed over the polar graph to ascertain whether the plotted points fall within the windows of the overlay

NOTE: For the polar graph, only the following two types of polar graph paper, or the equivalent, are suitable: #359-31 of Keuffel and Esser Company or #AC-0815-OT or GT of Graphic Controls Corporation.

CAUTION: Do not attempt to make copies of the polar graph or the overlay by photocopying or other duplicating processes that enlarge, reduce or distort the originals, as this will cause falsification of the test results. The Test Logs, however, may be reproduced to obtain working copies.

8. RECHECKS AND COMPLETE TEST REPETITION:

8.1 At the end of each test procedure the conditions for conformance (acceptability) are stated. If these are not met, the machine does not conform to the requirements.

8.2 A machine that would normally conform could, by chance, fail in a single test run. If so, two rechecks of the specific test conditions and procedures shall be made. The machine shall then conform in BOTH RECHECK TESTS to qualify as acceptable under the specified test.

NOTE: Between the failed test and the two recheck tests, only those types of adjustments to the machine shall be permitted that would not affect the results of any of the prior tests, were they to be run again.

8.3 If conformance in any test or recheck tests necessitates adjustment(s) of the machine that might affect the results of prior tests, ALL tests shall be repeated starting with 9.1.

9. PERFORMANCE TESTS AND TEST LOGS:

Table 2 lists the 10 individual performance tests and the number and size of test masses required for each test.

TABLE 2

Test	Section	Required Test Masses	Periodic Test (see Section 10)
Minimum achievable residual unbalance	9.1	1 x 20 A	Applicable
Sensitivity of amount indication	9.2	1 x 20 A	Applicable
Range and linearity of amount indication	9.3	1 x 40 A	Applicable
Heavy and light spot	9.4	1 x 40 A	Optional
Accuracy of amount and angle indication	9.5	2 x 2.5 A	Applicable
Simultaneous amount and angle indication	9.6	2 x 40 A	Optional
Plane separation	9.7	1 x 40 A	Applicable
Static and couple unbalance separation	9.8	2 x 40 A	Optional
Practical correction units	9.9	-	Optional
Minimum interference from drive	9.10	-	Applicable

NOTES: A minimum of 5 test masses is required for each size proving rotor, namely 2 x 2.5 A, 1 x 20 A, and 2 x 40 A.

In case of the 11-lb proving rotor, the two 2.5 A test masses are replaced by two sets of 10 and 12.5 differential test masses each.

9.1 Minimum Achievable Residual Unbalance (see Figure 1):

9.1.1 Specific Performance Requirements: The machine shall be capable of consistently balancing the proving rotor down to 0.5 A units or less of residual unbalance.

9.1.2 Test Conditions:

9.1.2.1 Set up the machine for indicating unbalance in the appropriate inboard proving rotor (see 4.6) according to the supplier's operating manual.

9.1.2.2 Adjust the amount of calibration of a soft-bearing machine or the radius setting of a hard-bearing machine, so that the readout is directly in units of A (or 0.01, 0.1, 10, 100, etc. times A) as convenient. Use a 20 A test mass for the soft-bearing machine calibration. Then remove the calibration mass. On a hard-bearing machine, determine the proper radius setting by measuring the radius (i.e., radial distance from the shaft axis) to the test mass center of gravity.

9.1.2.3 Using the normal operating procedure, indicate the rotor residual unbalance in planes 1 and 2. If it is less than 5 A units in either plane, apply unbalance mass to the rotor until the unbalance in each plane is between 5 and 20 A units.

9.1.3 Test Procedure:

9.1.3.1 Measure and then correct the indicated unbalance in both planes. Then measure and record the residual unbalance in both planes in the Test Log for 9.1.

9.1.3.2 Repeat 9.1.3.1 three more times, each time measuring the remaining unbalance, applying the indicated corrections, and then recording the new residual unbalance in both planes.

9.1.4 Conformance Requirement: All amount readings in lines 3 and 4 of the Test Log shall be no greater than 0.5 A units.

NOTE: Conformance provides no definite proof that the residual unbalance in the rotor is indeed no larger than 0.5 A units. However, such proof will be established by conformance with the test in 9.5 (see also Note 1 under 9.5.5).

9.2 Sensitivity of Amount Indication:

9.2.1 Specific Performance Requirements: All analog types of amount of unbalance readout devices shall have at least 1/8 in (3 mm) displacement of the pointer (or equivalent device) for an indication of 1 A unit over a range of 20 A units. All digital types of amount readout shall have at least 5 digits for an indication of 1 A unit over a range of 20 A units.

9.2.2 Test Procedure: Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), add a 20 A unit test mass to the rotor in plane 1, and indicate the unbalance.

9.2.3 Conformance Requirement: On machines with analog indication, the amount indication shall be displaced by at least 2.5 in (60 mm) indicator displacement. On machines with digital indication, the indication shall be no less than 100 digits.

9.3 Range and Linearity of Amount Indication:

9.3.1 Specific Performance Requirements: For unbalances of less than 5 A units in the proving rotor, the indicated amount shall not deviate more than 0.25 A units from the applied unbalance.

For unbalances of 5 A units or more, the indicated amount shall not deviate more than 5% from the applied unbalance.

The range of unbalance indication shall extend to at least 50 A units.

9.3.2 Test Procedure: Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), add a 40 A unit test mass at 270° to plane 1 of the proving rotor and indicate the unbalance. It is permissible to change the indicating sensitivity from that previously used by means of a sensitivity (range-multiplying) switch. For example, if for 9.1.4 one unit of the indicator scale represented 1 A unit, it may now be changed to represent 2 or 5 A units, without however affecting the calibration of the machine as set up for 9.1.

9.3.3 Conformance Requirement: The indicated amount of unbalance shall be between 38 A and 42 A units.

NOTE: The other requirements of 9.3.1 are proven by conformance with 9.5.

9.4 Indication of Heavy or Light Spot:

9.4.1 Specific Performance Requirements: With a 40 A unit test mass added to the proving rotor, the machine shall indicate selectibly either the heavy or light spot within 3° of the true position.

9.4.2 Test Procedure: Same as for 9.3.2.

9.4.3 Conformance Requirements: The indicated angle of unbalance shall be:

a. Between 267 and 273° when indication of the heavy spot is selected, or
b. Between 87 and 93° when indication of the light spot is selected.

9.5 Accuracy of Amount and Angle Indication (see Figure 2):

9.5.1 Specific Performance Requirements: With a stationary test mass in a given proving rotor plane, and a second test mass being moved from position to position ("traversed") in the same plane, all but one of the readings recorded in the Test Log and then plotted on the polar graph must be within the windows of the overlay.

9.5.2 Test Procedure:

9.5.2.1 Apply a 2.5 A test mass at any one of the following positions in plane 1 of the proving rotor: 15, 165, 195, or 345°. Call this position angle E. This is the stationary test mass. It remains in the same position for the tests in 9.5.2.2 and 9.5.2.3 except for the position marked with an asterisk (*) on the Test Log for 9.5. Add the E angle to each angle shown in column H of the Test Log and insert the result in column G.

9.5.2.2 Apply a second 2.5 A test mass (the "traveling" test mass) in successive runs at the positions in plane 1 as listed in column G on the Test Log. Record the amount and angle readings for plane 1 after each run for each position of the traveling test mass.

9.5.2.3 Repeat 9.5.2.2 twice more, always recording the readings in the Test Log.

9.5.3 Preparation of Polar Graph:

9.5.3.1 Plot the results on a polar graph of the type illustrated in Section 10, using the symbols shown in the left column of the Test Log.

9.5.3.2 Draw a line from the polar graph origin in the direction of E.

9.5.3.3 Place the overlay of Section 12 over the graph and adjust the position of the overlay so that:

a. Its 0 to 180° axis is parallel to the direction of E on the graph
b. The greatest possible number of plotted points is in their respective windows as indicated by the symbols
c. The origin of the overlay is within a radius of 0.5 A unit from the origin of the graph

9.5.4 Conformance Requirement: All but one of the plotted points shall be in their respective windows.

NOTE 1: If the machine conforms, the requirement of 9.1.1 is also proven due to the restriction in 9.5.3.3(c) to the graph adjustment.

NOTE 2: If two points or more fall outside their windows, the machine failed this test because of any number of reasons, e.g., lack of repeatability, amount, and/or angle indication errors, lack of sensitivity to small unbalances, etc.

9.5.5 Remove the test masses from plane 1 and apply them to plane 2, using a different value for the angle E. Then repeat 9.5.2 to 9.5.4 for the right plane, using a new Test Log and a new polar graph.

9.6 Simultaneous Amount and Angle Indication:

9.6.1 Specific Performance Requirement: The machine shall indicate simultaneously the amount and the angle of unbalance in both planes; however, indication in only one plane is permitted if indication in the other plane is obtainable by actuating a left-right (plane 1 - plane 2) switch.

9.6.2 Test Procedure: Same as for 9.3.2. Additionally, add a 40 A unit test mass at 270° to plane 2 of the proving rotor and indicate the unbalance simultaneously in plane 1 and plane 2; alternately, switch from plane 1 to plane 2.

9.6.3 Conformance Requirement: The amount and angle of unbalance shall be indicated simultaneously in plane 1 and in plane 2; alternately, sequential indication in plane 1 and plane 2 shall be permitted by actuating a left-right switch.

9.7 Plane Separation (see Figure 3):

9.7.1 Specific Performance Requirements: The machine shall indicate less than 2 A units of unbalance in the test plane near one end of the proving rotor when one 40 A unit test mass in added in the test plane near the other end of the rotor.

9.7.2 Test Procedure:

9.7.2.1 Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), apply a 40 A unit test mass in plane 2 of the proving rotor at 0° angle. Run the machine and record the indicated amount and angle for plane 1 in the Test Log for 9.7. Stop and start the machine twice more, each time recording the readings for plane 1.

9.7.2.2 Move the test mass in plane 2 to the 90° position. Start and stop the machine 3 times in succession, each time recording the readings for plane 1.

9.7.2.3 Repeat 9.7.2.2 twice more but with the test mass at 180° and then at 270°.

9.7.2.4 Move the test mass to plane 1 and repeat 9.7.2.1 to 9.7.2.3, in each case recording the readings for plane 2.

9.7.3 Preparation of Polar Graph: Plot the recorded readings into the polar graph of Section 11 using a plus (+) symbol, place the overlay of Section 12 over the polar graph in the same position as in 9.5.3.3.

9.7.4 Conformance Requirement: All plotted points shall be within the separation circle of the overlay.

NOTE: It is permissible to adjust the position of the overlay within the rules of 9.5.3.3 to obtain conformance, provided that the plotted results of prior tests still show conformance also.

9.8 Static and Couple Unbalance Separation (see Figure 4):

9.8.1 Specific Performance Requirements: The machine shall indicate 2 A units of unbalance or less in a given static unbalance correction plane of the proving rotor when one 40 A unit test mass is added in each of two selected couple unbalance correction planes simultaneously and at opposite angular locations. The machine shall also indicate 2 A units or less of unbalance in the couple unbalance correction planes when one 40 A unit test mass is added in the static correction plane.

9.8.2 Test Procedure:

9.8.2.1 Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), set up the machine according to the Supplier's operating manual to indicate static unbalance in plane 3 of the proving rotor and couple unbalance in planes 1 and 2. Indicate the heavy spot on the rotor.

9.8.2.2 Apply one 40 A unit test mass at 60° in plane 1 of the proving rotor, and another 40 A unit test mass in plane 2 at 240°.

9.8.2.3 Run the machine and record the indicated static unbalance in the Test Log for 9.8.

9.8.2.4 Move both test masses successively to the angles shown in the Test Log for three more runs and each time record the indicated static unbalance.

9.8.2.5 Remove the test masses from planes 1 and 2 and apply a single 40 A unit test mass at 60° in plane 3.

9.8.2.6 Run the machine and record the indicated couple unbalance in the Test Log.

9.8.2.7 Move the test mass successively to the angles shown in the Test Log for three more runs and each time record the indicated couple unbalance.

9.8.3 Preparation of Polar Graph: Plot the static readings on a (new) polar graph of Section 11 using a plus (+) symbol, and plot the couple readings using an encircled dot (⊙) symbol. Place the overlay of Section 12 over the polar graph in the same position as in 9.7.3.

9.8.4 Conformance Requirement: All plotted points shall be within the separation circle.

9.9 Practical Correction Units:

9.9.1 Specific Performance Requirements: The machine shall be capable of indicating unbalance directly in terms of practical correction units such as ounces, grams, ounce·inches, number of standardized washers or weights, etc.

9.9.2 Test Conditions and Procedure: Because of the many different types of unbalance indicating devices, it is considered impractical to establish specific conditions and procedures for testing this capability.

9.9.3 Conformance Requirement: In the absence of specific conditions and procedures it is nevertheless important that the Supplier demonstrate to the User that the machine will, when the instructions in the operating manual are followed, indicate unbalance in practical correction units as cited in 9.9.1 without significant loss in sensitivity and indicating range.

9.10 Minimum Interference From Drive (see Figure 5):

9.10.1 Specific Performance Requirements: The disturbance from the drive system shall not result in a balance error in excess of 0.5 A units.

NOTES:

1. The drive systems includes all components necessary to drive the proving rotor.
2. If there is no fixed angular relationship between rotor and machine as is the case on belt-drive machines with stroboscopic angle indication, this test is deleted.

9.10.2 Test Procedure:

9.10.2.1 Starting with the balanced proving rotor (i.e., same as after 9.1.3.2) read and record the residual amount and angle of unbalance for planes 1 and 2 in the Test Log for 9.10 as Run #1. This configuration is listed as Drive Angle 0°.

9.10.2.2 Index the rotor 180° with respect to the drive and/or measuring system of the balancing machine. In the case of end-drive systems this is done by uncoupling the end-drive from the rotor. If belt drive is used, the phase reference pick-up should be rearranged to change the phase by 180°. Read and record the amount and angle of unbalance in planes 1 and 2 in the Test Log as Run #2. This configuration is listed as Drive Angle 180°. Reverse the angle by adding or subtracting 180° as indicated in the Test Log.

9.10.2.3 Index the rotor again by 180°, thereby returning to the position of 9.10.2.1. Repeat the readings but record them in the Test Log as Run #3.

9.10.2.4 Repeat 9.10.2.2 but record the readings in the Test Log as Run #4.

9.10.3 Preparation of Polar Graph: Plot the readings for plane 1 in a (new) polar graph of Section 10 using a plus (+) symbol for Runs #1 and #3, and an encircled dot (·) for Runs #2 and #4. Find the midpoint P between the two plus symbols, and the midpoint O between the two encircled dots. A typical plot is shown under the Test Log. On a separate polar graph plot the readings for plane 2 in like manner.

9.10.4 Conformance Requirement: The distance between points P and Q in each of the plots for planes 1 and 2 shall be less than 1 A unit.

NOTE: On end-drive machines means shall be provided to make unbalance corrections on the end-drive flange near the proving rotor.

	PLANE 1		PLANE 2	
Line	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees
1				
2				
3				
4				

FIGURE 1 - Test Log for 9.1 - Minimum Achievable Residual Unbalance

Angle E of Stationary Test Mass =

			Plane 1 or 2 Indicated Unbalance					
			1st Run		2nd Run		3rd Run	
Symbol	Angle H Degrees	Angle G Traveling Test Mass Degrees G = H + E (or H + E - 360)	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees
	15							
	60							
	90							
	120							
	150							
	165							
	*	N.A.						
	195							
	210							
	240							
	270							
	300							
	330							

*For this set of readings remove both the stationary and the traveling test masses. Be sure to re-install the stationary test mass again at E after this run.

FIGURE 2 - Test Log for 9.5 - Accuracy of Amount and Angle Indication

Angle of 40 A Test Mass Degrees	Indicated Unbalance					
	1st Run		2nd Run		3rd Run	
	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees
Plane 2	Plane 1		Plane 1		Plane 1	
0						
90						
180						
270						
Plane 1	Plane 2		Plane 2		Plane 2	
0						
90						
180						
270						

FIGURE 3 - Test Log for 9.7 - Plane Separation

Angle of 40 A Test Mass Degrees		Indicated Unbalance	
		Amount A Units	Angle Degrees
Plane 1	Plane 2	Static Unbalance Indication	
60	240		
150	330		
240	60		
330	150		
Plane 3		Couple Unbalance Indication	
60			
150			
240			
330			

FIGURE 4 - Test Log for 9.8 - Static and Couple Unbalance Separation

Run #	Drive Angle Degrees	Indicated Unbalance					
		Plane 1			Plane 2		
		Amount A Units	Angle J Degrees	Reversed Angle K Degrees K=J±180	Amount A Units	Angle M Degrees	Reversed Angle N Degrees N=M±180
1	0		+			⊡	
3	0		+			⊡	
2	180			⊙			△
4	180			⊙			△

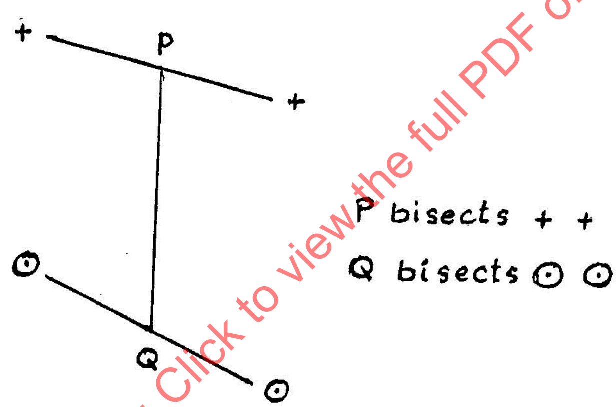


FIGURE 5 - Test Log for 9.10 - Minimum Interference from Drive

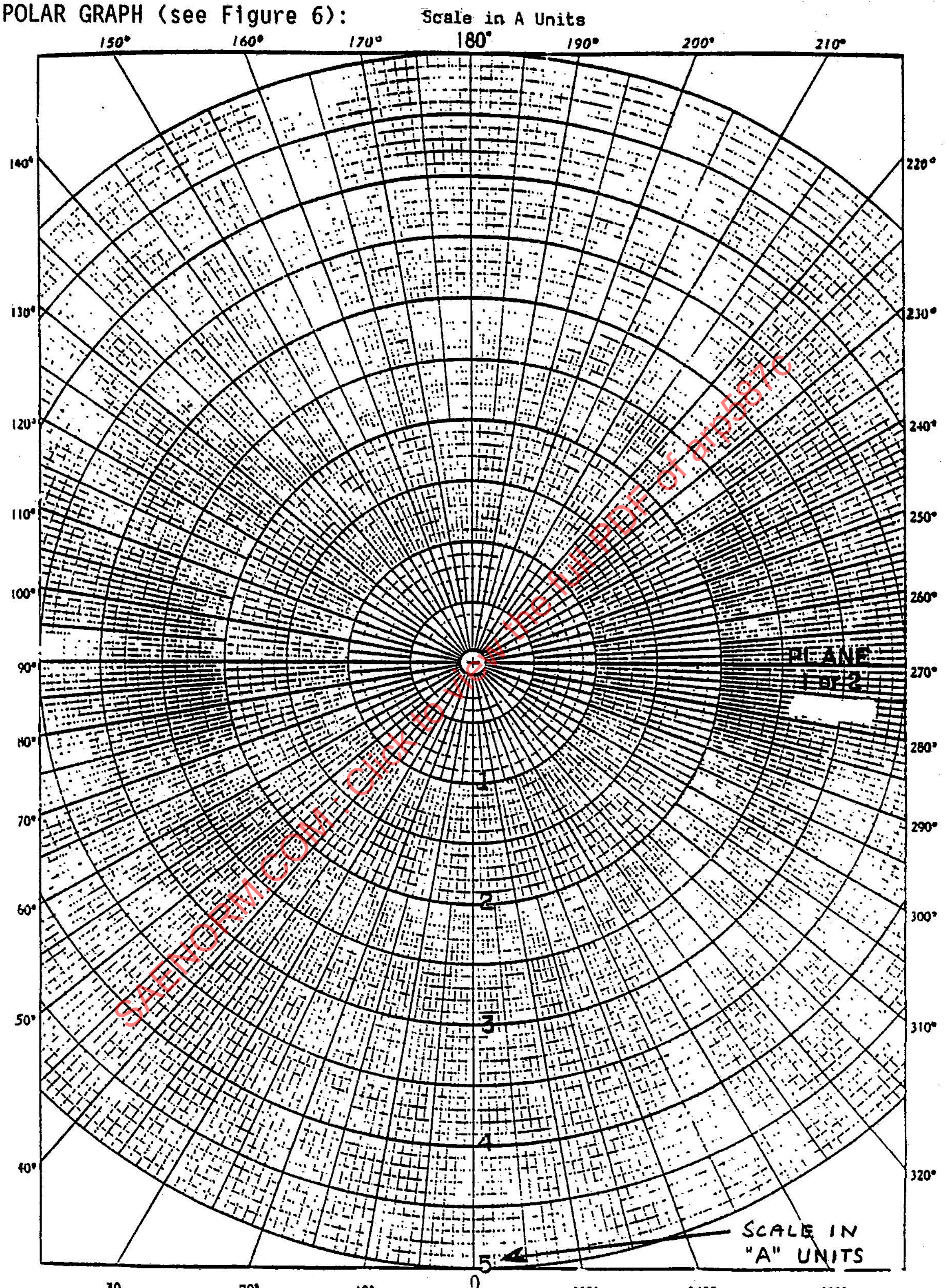
10. PERIODIC TEST PROCEDURE:

Each balancing machine shall be tested periodically and/or after repairs that may have affected its performance. The test procedure for such periodic tests shall be the same as described in Section 9 except that it may be shortened by deleting those parts of the test designated optional in the last column of Table 2.

The Periodic Test Procedure replaces ARP1340 in its entirety.

PREPARED BY SAE SUBCOMMITTEE EG-1A, BALANCING OF THE
SAE COMMITTEE EG-1, AEROSPACE PROPULSION SYSTEMS SUPPORT EQUIPMENT

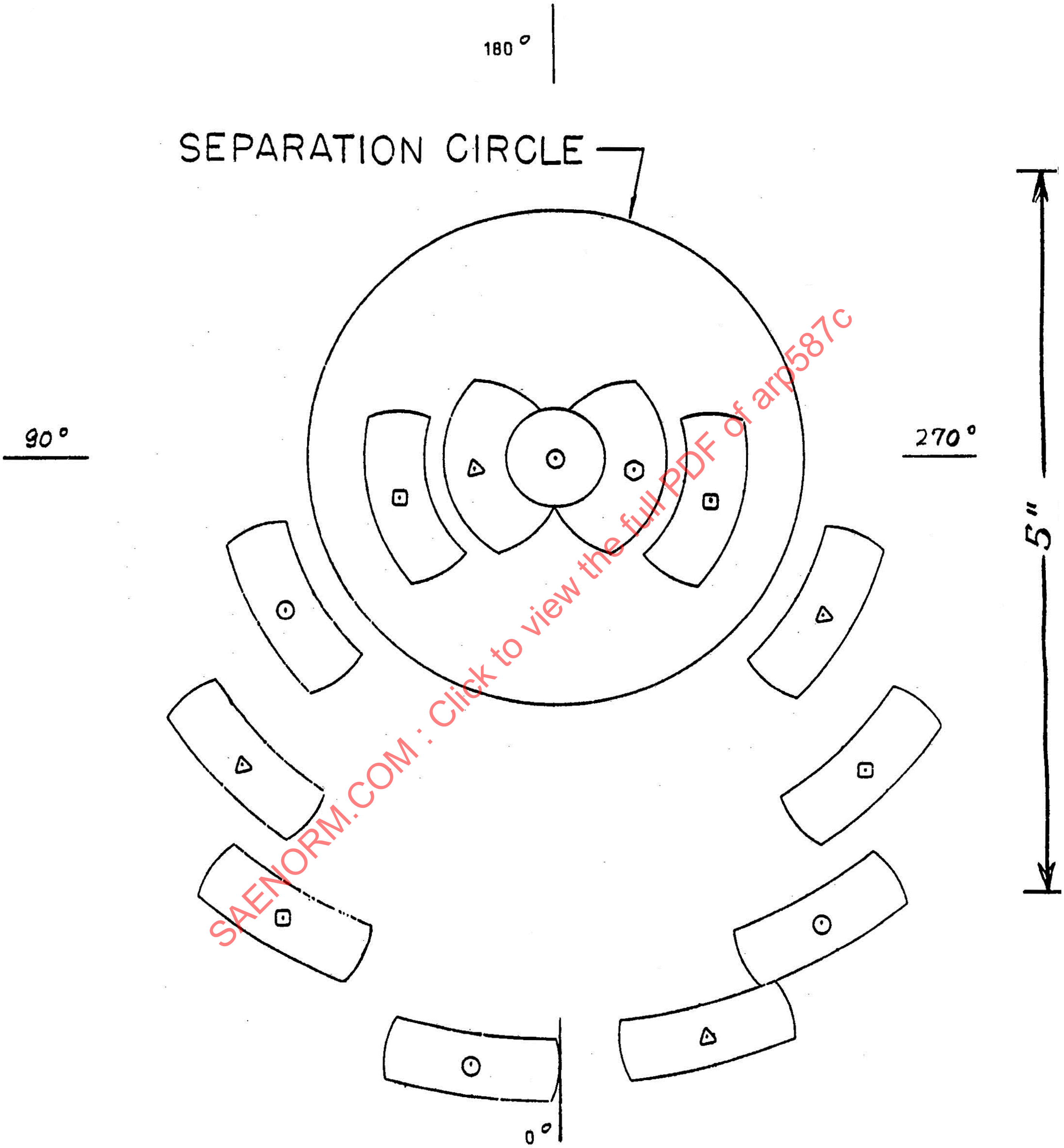
11. POLAR GRAPH (see Figure 6):



CAUTION: This page has been photographically reduced. Therefore, it is not suitable for recording readings. Use only the original paper specified in 7.4.

FIGURE 6

12. OVERLAY (see Figure 7):

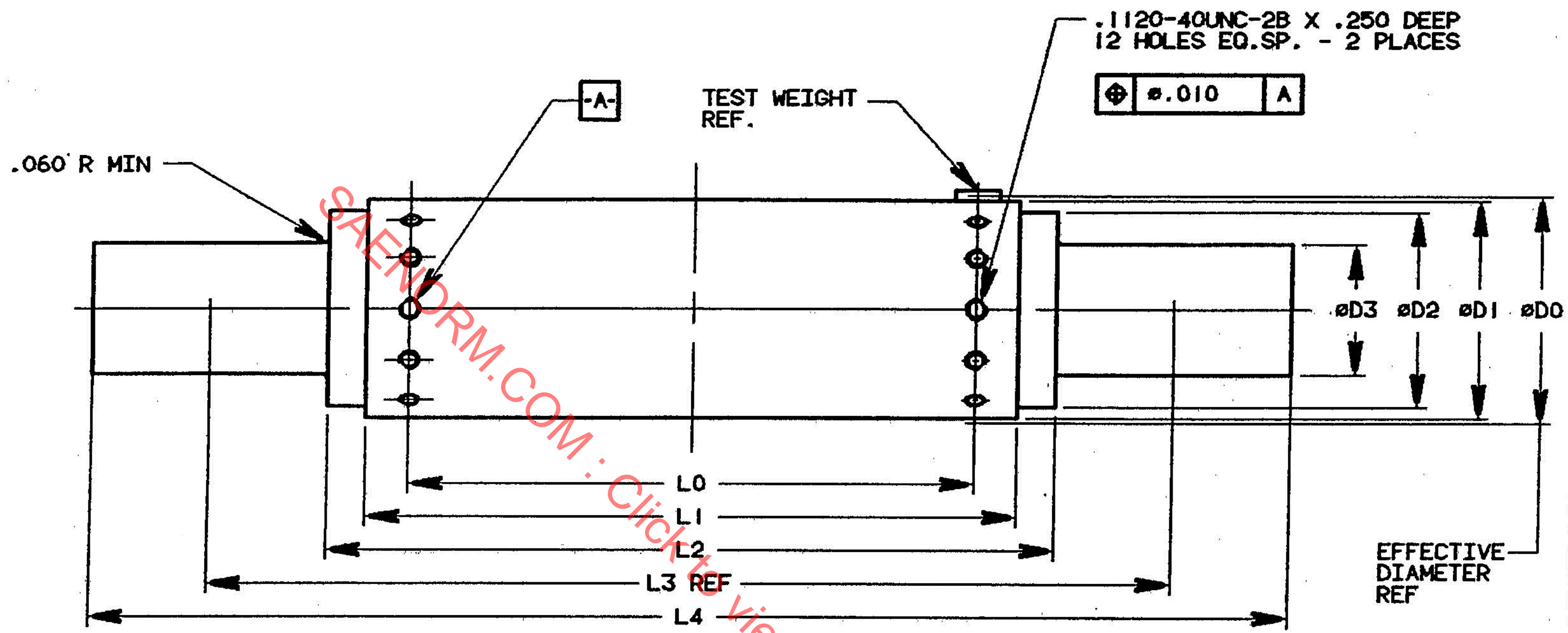


CAUTION: This is a photographically reduced sample of the overlay. It is not suitable for evaluating test results. Use only the transparent overlay furnished with this document for evaluating test results.

FIGURE 7

APPENDIX A

ALL DIMENSIONS ARE IN INCHES



UNLESS OTHERWISE SPECIFIED:
CONCENTRICITY WITHIN: .0002 FIR
DIMENSIONS: ±.002 FIR

SCALE 1/2

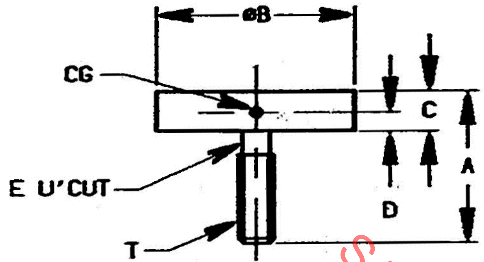
WEIGHT	D0	D1	D2	D3	L0	L1	L2	L3	L4
11 LBS	2.4000	2.3000	2.0625	1.3750	6.0000	6.9000	7.7106	10.2106	12.7106

MATERIAL: SAE4140 HDN ROCK C 40-45

BLACK OXIDE PER AMS2486

STORAGE/SHIPPING CONTAINER REQUIRE

FIGURE A1A - 11 lb SAE Proving Rotor



W=WEIGHT(OZ)
SCALE 2/1

MATERIAL: 40A STEEL SAE4140 (0.2835 LB/IN ^{3})
20A ALUMINUM 6061-T6 (0.0975 LB/IN ^{3})
12.5A PENNLON (0.0341 LB/IN ^{3})
10A PENNLON (0.0341 LB/IN ^{3})

NOTE 2: TEST MASS CALCULATIONS ARE BASED ON PROVING ROTOR WEIGHTS & MOMENTS OF INERTIA (SEE ALSO B.10 AND B.11)

14.5 MICROINCH DISPLACEMENT				
	40A	20A	12.5A	10A
A	0.3528	0.3296	0.3097	0.3157
B	0.2073	0.2785	0.4135	0.3577
C	0.1653	0.1421	0.1222	0.1282
D	0.0500	0.0500	0.0500	0.0500
W	0.0307	0.0154	0.0096	0.0077
E	0.0780 DIA X 0.0625			
T	0.1120-40UNC-2A BLUNT START			

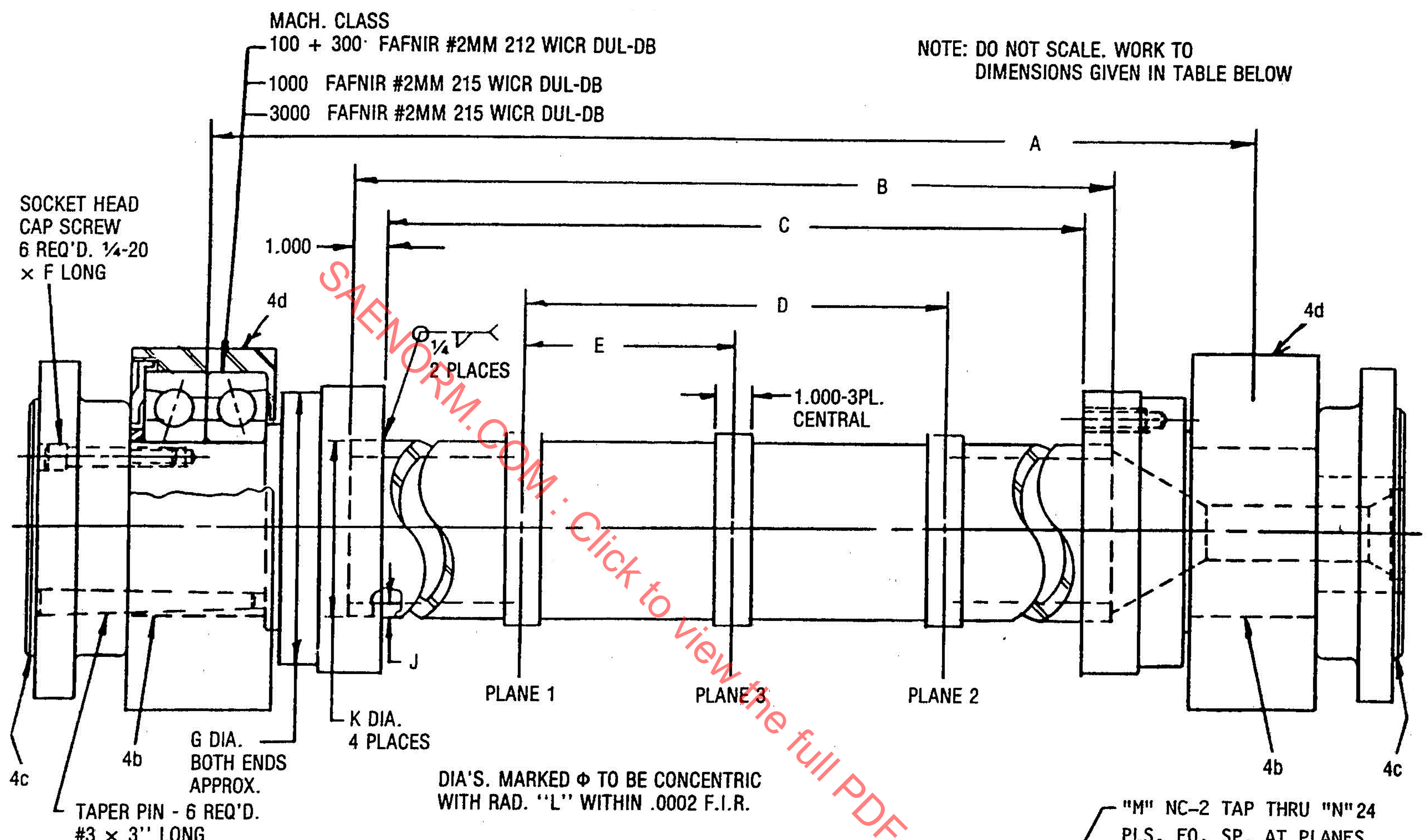
10.0 MICROINCH DISPLACEMENT				
	40A	20A	12.5A	10A
A	0.3923	0.3525	0.3208	0.3302
B	0.1470	0.2078	0.3233	0.2756
C	0.2048	0.1650	0.1333	0.1427
D	0.0500	0.0500	0.0500	0.0500
W	0.0212	0.0106	0.0066	0.0053
E	0.0780 DIA X 0.0625			
T	0.1120-40UNC-2A BLUNT START			

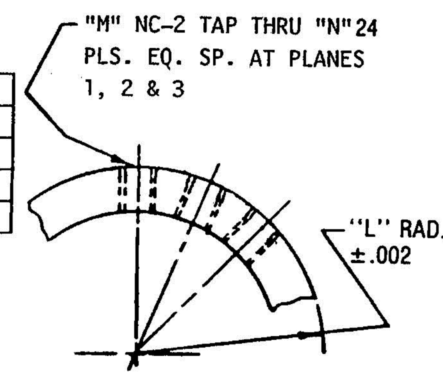
BLACK OXIDE STEEL DETAILS PER AMS2486

NOTE 1: PENNLON MANUFACTURED
BY DIXON CORP.
METACOM AVE.
BRISTOL, RI
02809 USA

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS: ±.001 FIR

FIGURE A1B – 11 lb SAE Proving Rotor Test Masses





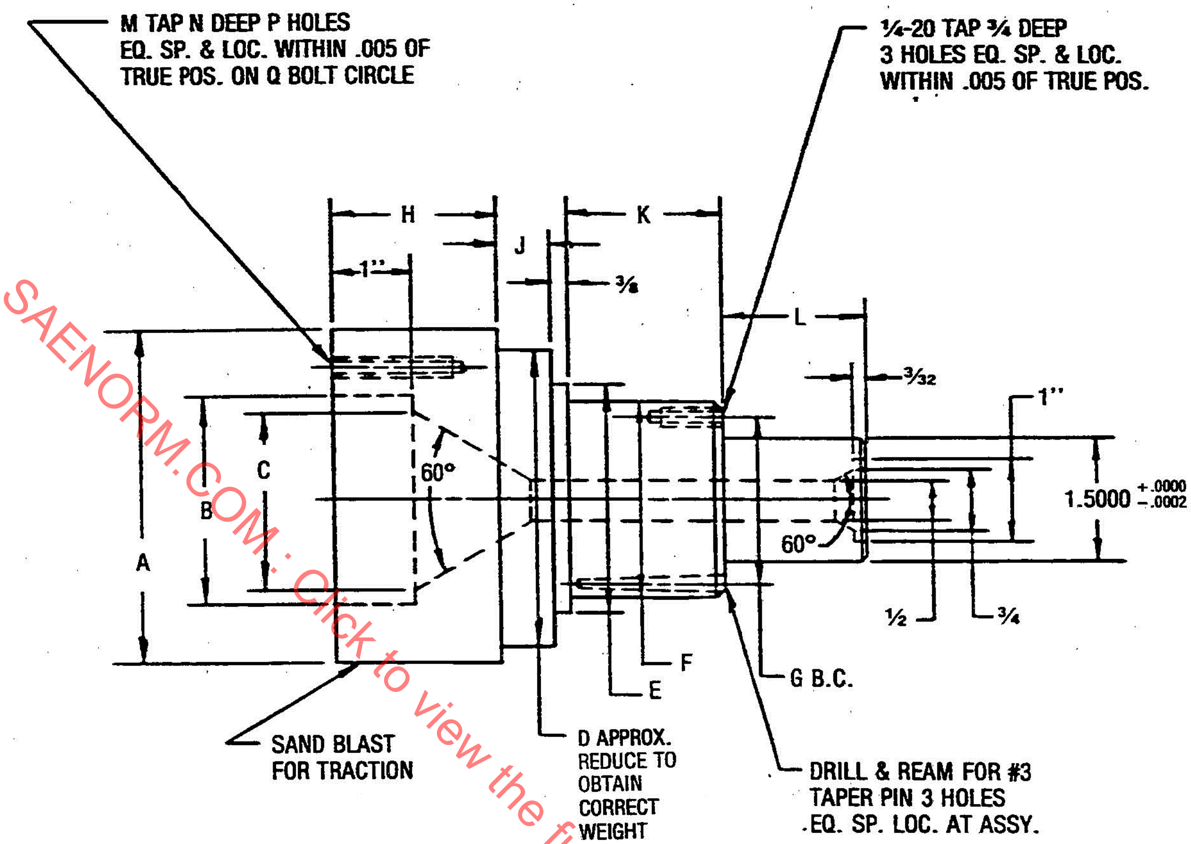
MACH. CLASS	A	B	C	D	E	F	G	H	J	K	L	M	N
100	23.625	17.175	15.175	8.000	4.000	1½	2.877	51.75	.234	2.469	1.2500	8-32	3/16
300	23.625	17.175	15.175	8.000	4.000	1½	2.877	51.75	.234	2.469	1.2500	8-32	3/16
1000	38.250	29.000	27.000	15.000	7.500	2	5.889	170.0	.468	3.937	2.000	1/4-20	9/32
3000	83.180	73.000	71.000	40.000	20.000	2	10.875	452.65	.500	6.937	3.550	5/16-18	11/32

STRESS RELIEVE BEFORE FINISH MACHINING

MACHINE DIA. G TO MAINTAIN
TOTAL WEIGHT OF H POUNDS ± .25%
MATERIAL - STEEL AISI 4140-4150

BLACK OXIDE PER AMS 2485C ALL STEEL DETAILS IN DETAIL

FIGURE A1C - Proving Assembly for 100, 300, 1000 and 3000 lb Class Machines

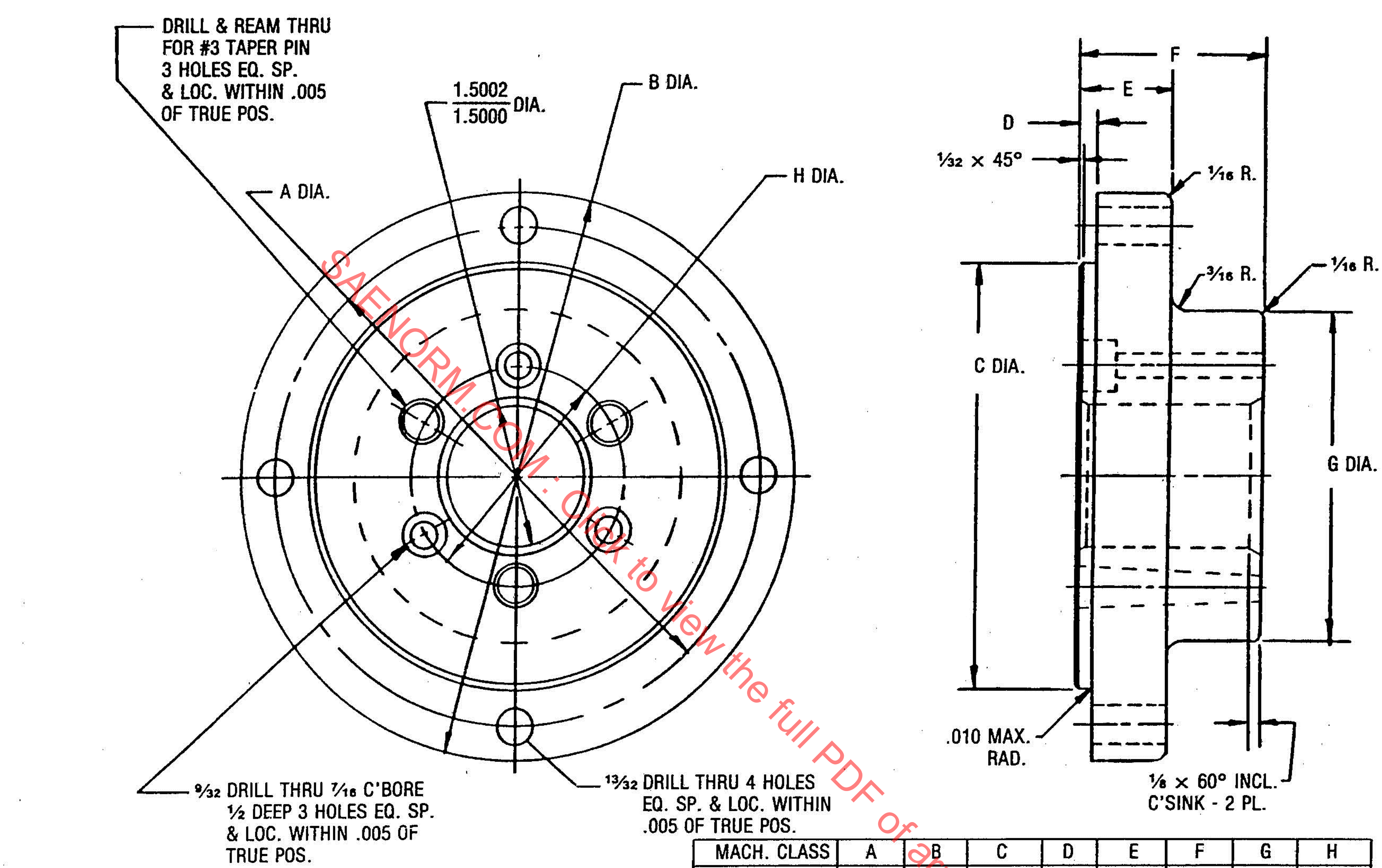


MACH. CLASS	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
100	4.000	2.469	2⅛	2.877	2¾	2.3624	2.0000	1¾	1 15/64	1.898	1 7/16	¼-20	1½	12	3.000
300	4.000	2.469	2⅛	2.877	2¾	2.3624	2.0000	1¾	1 15/64	1.898	1 7/16	¼-20	1½	12	3.000
1000	6.625	3.9375	3⅛	5.889	3⅜	2.9530	2.3125	3½	49/64	2.218	1 15/16	⅜-16	2	16	6.000
3000	11.000	6.9375	6	7.541	3⅜	2.9530	2.3125	3 13/16	59/64	2.218	1 15/16	⅜-16	2	16	10.000

2 REQ'D. - STEEL - AISI 4140-4150

NOTE: DO NOT SCALE. WORK TO DIMENSIONS GIVEN IN TABLE ABOVE

FIGURE A1D - Stub Shaft for 100, 300, 1000 and 3000 lb Class Machine Rotor

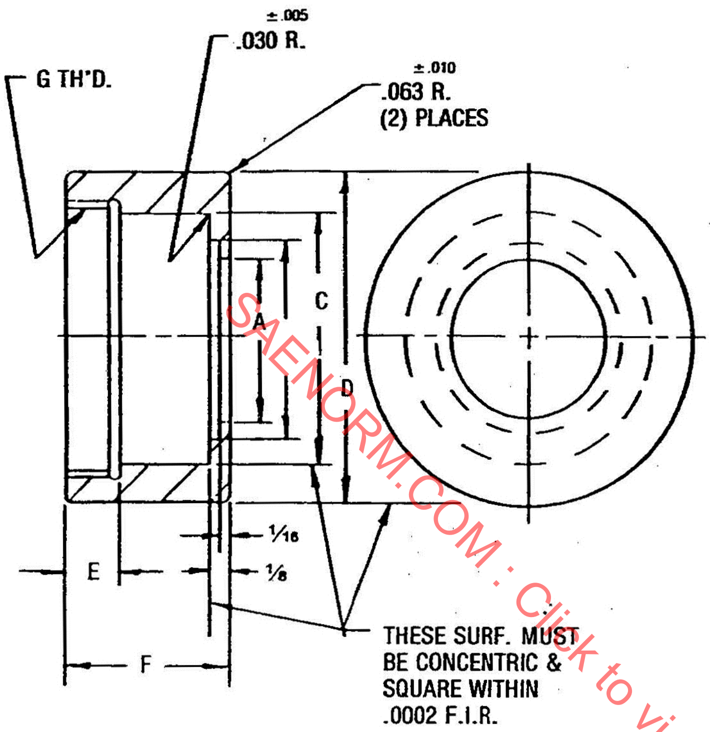


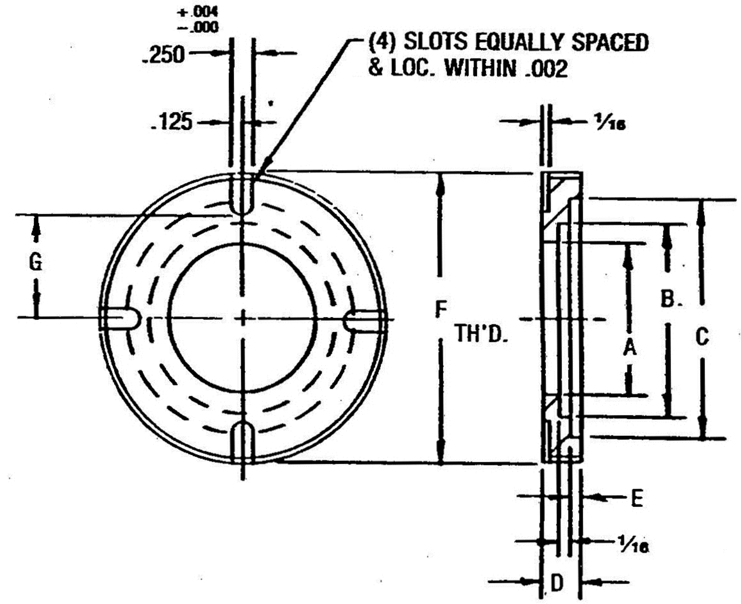
2 REQ'D. - STEEL - AISI 4140-4150

MACH. CLASS	A	B	C	D	E	F	G	H
100	4.125	4.750	3.5000 3.4998	.115 .110	.750	1.500	3.500	2.000
300	4.125	4.750	3.5000 3.4998	.115 .110	.750	1.500	3.500	2.000
1000	5.250	6.000	4.5000 4.9998	.175 .170	1.000	2.000	3.500	2.3125
3000	6.250	7.000	5.5000 5.4998	.175 .170	1.000	2.000	4.500	2.3125

*Interface dimensions shown are those of older style rotors in accordance with ARP587A.
For new rotors use interface dimensions as shown in ARP1382.

FIGURE A1E - Coupling with End-Drive Interface* for 100, 300, 1000 and 3000 lb Class Machine Rotors





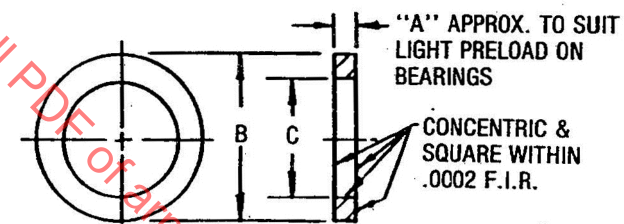
MACH. CLASS	A ±.005	B ±.010	C ±.010	D ±.010	E ±.010	F TH'D.	G ±.010
100	2.770	3.500	4.375	.250	.093	4¾-12	1.875
300	2.770	3.500	4.375	.250	.093	4¾-12	1.875
1000	3.395	4.000	4.760	.219	.063	5¼-12	2.125
3000	3.395	4.000	4.760	.219	.063	5¼-12	2.125

2 REQ'D. – STEEL – AISI A2 OR A6 – HDN. Rc 38-42

MACH. CLASS	A	B +.005 −.010	C +.000 −.000	D +.001 −.001	E +.000 ±.010	F ±.010	G TH'D.
100	2.770	3.500	4.3307	5.000	.375	2.000	4¾-12
300	2.770	3.500	4.3307	5.000	.375	2.000	4¾-12
1000	3.395	4.760	5.1181	6.000	.281	2.312	5¼-12
3000	3.395	4.760	5.1181	6.000	.281	2.312	5¼-12

(2) REQ'D. – STEEL – AISI A2 OR A6
HDN. Rc 50-55

NOTE: DO NOT SCALE. WORK TO DIMENSIONS GIVEN



(2) REQ'D. – STEEL – AISI A2 OR A6 HDN. Rc 50-55

MACH. CLASS	A	B +.000 −.010	C +.0010 −.0000
100	.166	2.750	2.3634
300	.166	2.750	2.3634
1000	.266	3.375	2.9540
3000	.266	3.375	2.9540

NOTE: ASSEMBLE DUPLEX BEARINGS BACK-TO-BACK WITH FACES MARKED "DB" FACING EACH OTHER AND ALIGN MATCH MARKS OF INNER RACES TO EACH OTHER AND OF OUTER RACES TO EACH OTHER

FIGURE A1F – Bearing Retainer Assembly for 100, 300, 1000 and 3000 lb Class Machine Rotors

A = (MICRO-INCH	TEST MASS x A	WEIGHT ±.0005 (OZ)	EFFECT RADIUS R (IN)	UNBAL. VALUE *1 (OZ·IN)	B (IN)	C REF. (IN)	D (IN)	E 0 (IN)	F THREAD (IN)	G (IN)	MATERIAL
52 LB. PROVING ROTOR FOR 100 AND 300 LB. CLASS MACHINE											
10	2.5	.0111	1.335	.0148	.2275	.375	.085	.120	#8-32	.250	Pennl. *2
10	20	.0847	1.398	.1185	.407	.375	.148	.120	#8-32	.250	ALUM. *3
10	40	.1716	1.381	.2370	.332	.375	.131	.120	#8-32	.250	STEEL *4
14.5	2.5	.0157	1.365	.0215	.285	.375	.115	.120	#8-32	.250	PENNL. *2
14.5	20	.1218	1.410	.1718	.500	.375	.160	.120	#8-32	.250	ALUM. *3
14.5	40	.2485	1.398	.3436	.407	.375	.148	.120	#8-32	.250	STEEL *4
170 LB. PROVING ROTOR FOR 1000 LB. CLASS MACHINE											
10	2.5	.0217	2.002	.0435	.2898	.375	.0022	.125	.250-20	.375	PENNL. *2
10	20	.1605	2.167	.348	.471	.500	.167	.125	.250-20	.375	ALUM. *3
10	40	.3264	2.132	.696	.378	.500	.132	.125	.250-20	.375	STEEL *3
14.5	2.5	.0307	2.056	.0631	.375	.375	.056	.125	.250-20	.375	PENNL. *2
14.5	20	.230	2.192	.504	.5791	.500	.192	.125	.250-20	.375	ALUM. *3
14.5	40	.4656	2.167	1.009	.4703	.500	.167	.125	.250-20	.375	STEEL *4
460 LB. PROVING ROTOR FOR 3000 LB. CLASS MACHINE											
10	2.5	.0313	3.534	.1105	.3968	.275	.016	.239	5/16-18	.313	PENNL. *2
10	20	.2338	3.780	.8839	.500	.639	.230	.239	5/16-18	.313	ALUM. *3
10	40	.4832	3.659	1.768	.500	.418	.109	.239	5/16-18	.313	STEEL *4
14.5	2.5	.0446	3.589	.1602	.500	.300	.039	.239	5/16-18	.313	PENNL. *2
14.5	20	.3585	3.575	1.282	.500	.279	.025	.239	5/16-18	.313	STEEL *4
14.5	40	.6947	3.690	2.563	.625	.420	.140	.239	5/16-18	.313	STEEL *4

*1 Unbalance value = weight x effective radius.
*2 Pennlon manufactured by Dixon Corp., Metacom Ave., Bristol, RI 02890, USA
*3 Aluminum SAE 6061-T6
*4 Stainless Steel SAE 304
* Test mass calculations are based on proving rotor weights and moments of inertia (see also A.2.10 and A.2.11)

NOTE: TEST MASS CALCULATIONS ARE BASED ON PROVING ROTOR MOMENTS OF INERTIA

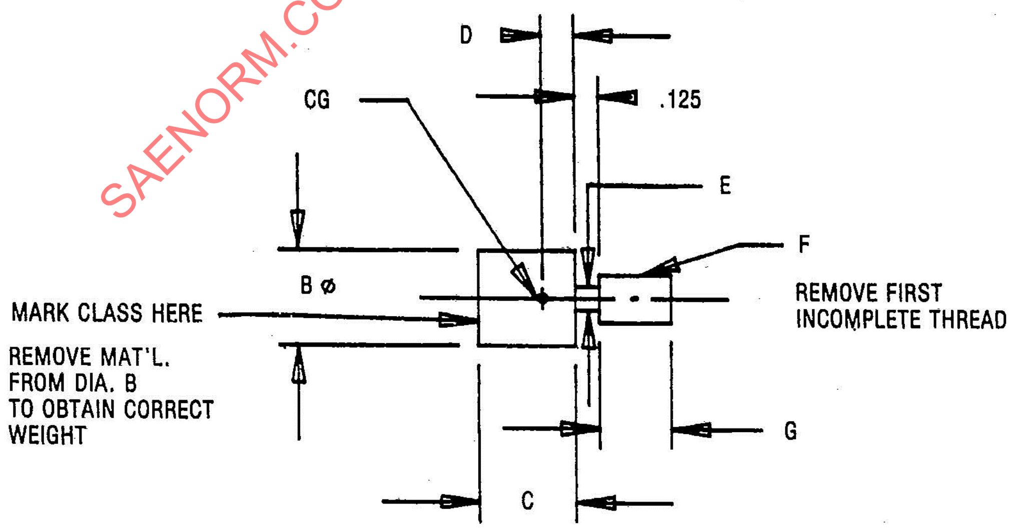


FIGURE A2 - Test Masses for 52 lb and Larger Proving Rotors

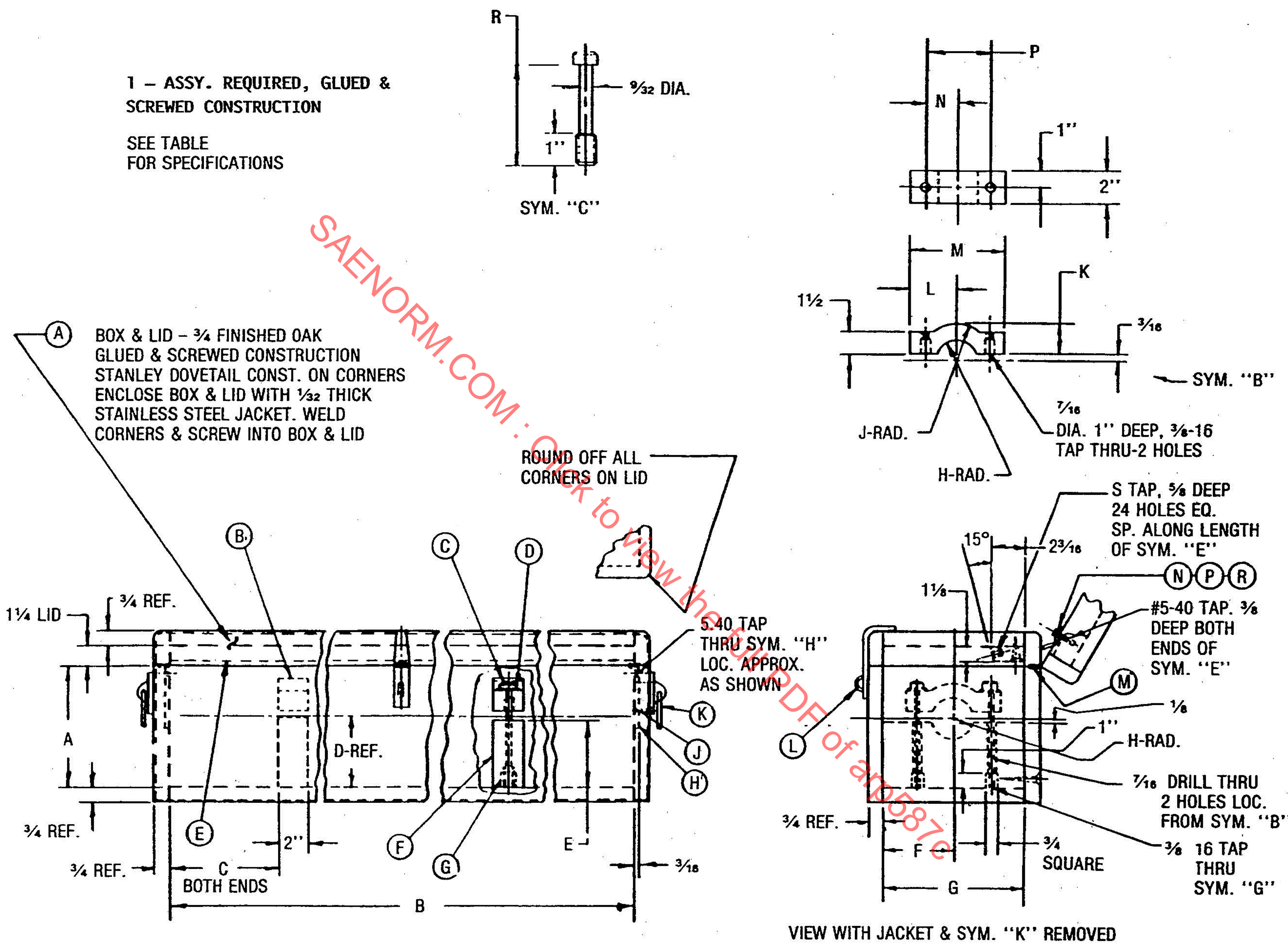


FIGURE A3 – Proving Rotor Storage Containers

TABLE A1 - Dimensions for Proving Rotor Storage Containers

Sym.	No. Req.	Material	Dim.	Machine Classes 100+ 300	1000	3000
A	1	3/4 Finished Oak	A	5-3/4	8-1/4	12-1/2
B	2	AISI 1018-1020	B	30-1/8	47	90-31/32
C	4	Soc. Hd. Cap Scr. -3/8-16 x "R" Lg	C	7-3/4	9-13/16	10-9/32
D	4	Washer -3/8 Std.	D	3	4-1/2	6-1/2
E	1	AISI 1018-1020	E	2-7/8	4-3/8	6-3/8
F	2	2" Finished Oak	F	3-1/8	4-5/8	6
G	4	AISI 1018-1020	G	6-1/4	9-1/4	12
H	2	AISI 1018-1020	H	1-1/4	2	3-1/2
J	8	Flat Hd. Scr. #10-24 x 7/8	J	2-3/8	2-3/8	4-1/4
K	2	Stanley Chest Handle 1205-4	K	2-3/16	2-3/16	4-1/16
L	1	Stanley Hinge Hasp 912-6	L	3-1/16	3-1/16	5-1/8
M	1	Stanley Cont. Hinge #311 x 1-1/4 Wide	M	6-1/8	6-1/8	10-1/4
N	2	Carr Lane Cable #CL-23-KA-4	N	2-3/8	2-3/8	4-1/2
P	4	Button Hd. Cap Scr. #5-40 x 1/4	P	4-3/4	4-3/4	9
R	4	Washer #5 Std.	R	4-1/2	5-3/4	8
			S	8-32	1/4-20	5/16-18

An equivalent storage container for the 11 lb proving rotor is recommended.

APPENDIX B

DEFINITIONS OF SYMBOLS AND TERMS

Definitions are given for those technical terms that have a particular meaning for this document. Some of these terms have been written with capitals throughout the document, particularly where they have a definite meaning in a specific context. The more general use of the same word has not been capitalized. An attempt has been made throughout to use the same words to express the same idea. The definitions are listed in the approximate order in which they first occur. In general, the terminology of ISO-1925 and ANSI S2.7 has been used.

B.1 SYMBOLS:

- U Unbalance (oz·in)
- Ä Units - Required sensitivity of the machine in microinches. See also A.2.10
- W Weight of the proving rotor (lb)
- r Radius of the center of gravity (c.g.) of W or w from the shaft axis (in)
- I_X Moment of inertia of the proving rotor about a transverse axis through its c.g. (lb·in^2)
- I_Z Moment of inertia of the proving rotor about its axis of rotation (lb·in^2)
- d Distance between the couple unbalance or the dynamic unbalance planes (in)
- D Distance between the bearing mid-points (in)
- w Weight of unbalance mass in ounces at a given correction radius of a rotor or part
- V Units - An amount of unbalance which causes a 1 microinch displacement of the rotor center of gravity (or bearing mid-points, as applicable) if the rotor were rotating unconstrained in gravitationless space

B.1.1 Subscripts:

- S For static unbalance
- C For couple unbalance
- 1 For plane 1 on proving rotor
- 2 For plane 2 on proving rotor
- 3 for mid-plane on proving rotor

B.1.2 Microinch:

1 μin = 10^{-6} in